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A MININEC MODEL OF THE MINILoop ANTENNA(U) NAVAL OCEAN  
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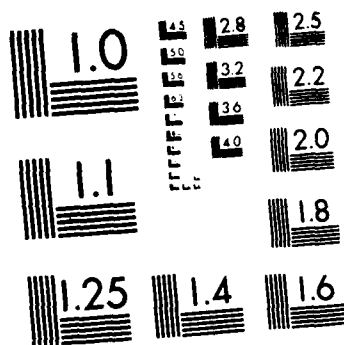
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## AD-A191 759 PORT DOCUMENTATION PAGE

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2b DECLASSIFICATION / DOWNGRADING SCHEDULE			Approved for public release; distribution is unlimited.	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)			5 MONITORING ORGANIZATION REPORT NUMBER(S)	
NOSC				
6a NAME OF PERFORMING ORGANIZATION		6b OFFICE SYMBOL (if applicable)	7a NAME OF MONITORING ORGANIZATION	
Naval Ocean Systems Center		NOSC	Naval Ocean Systems Center	
8c ADDRESS (City, State and ZIP Code)			7b ADDRESS (City, State and ZIP Code)	
San Diego, CA 92152-5000			San Diego, CA 92152-5000	
8a NAME OF FUNDING / SPONSORING ORGANIZATION		8b OFFICE SYMBOL (if applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
Naval Ship Research and Development Center		NSRD		
8c ADDRESS (City, State and ZIP Code)			10 SOURCE OF FUNDING NUMBERS	
Bethesda, MD 20084			PROGRAM ELEMENT NO	PROJECT NO
			62543 N	CM41
			TASK NO	AGENCY ACCESSION NO
			RF45405	DN213 105
11 TITLE (include Security Classification)				
A Mininec Model of the Miniloop Antenna				
12 PERSONAL AUTHOR(S)				
J.C. Logan				
13a TYPE OF REPORT		13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Presentation/speech		FROM Mar 1987 TO Mar 1987	October 1987	
16 SUPPLEMENTARY NOTATION				
17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP		
			HF antennas	
			nondeliberate interactions	
19 ABSTRACT (Continue on reverse if necessary and identify by block number)				
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20 DISTRIBUTION / AVAILABILITY OF ABSTRACT			21 ABSTRACT SECURITY CLASSIFICATION	
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22 NAME OF RESPONSIBLE INDIVIDUAL			22a TELEPHONE (include Area Code)	22b OFFICE SYMBOL
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A MININEC MODEL OF  
THE MINILOOP ANTENNA

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## ABSTRACT

The Miniloop is an HF loop antenna which has found use on U.S. Coast Guard vessels. The antenna is a large diameter loop mounted on a pedestal. It is tuned with a variable capacitor mounted in series at the top of the loop. Inductive coupling from a much smaller loop on the lower rim is used as a feed.

MININEC (NOSC TD 938, \*The New MININEC Version 3); a Mini-Numerical Electromagnetics Code\*, by J. W. Rockway and J. C. Logan, September 1986, is used to represent the Miniloop antenna mounted over a perfectly conducting ground plane. The development and validation of the MININEC model of the Miniloop will be discussed. A sample method for determining radiation efficiency will also be presented.

## INTRODUCTION

In general, HF antennas mounted on ships will couple into metallic parts of the ship. This means that strong RF currents can be excited on closely coupled conducting surfaces, which in turn re-radiate. The total near field is the (vector) sum of the fields radiated by the antenna, the deliberate antenna, and the non-deliberate antennas. Re-radiation is enhanced whenever the non-deliberate antennas are similar in size to the deliberate antennas, or whenever resonant length conducting paths and spacings occur.

A computer model can be used to include the deliberate and non-deliberate interactions to accurately predict the near fields on exposed weather decks. This usually involves creating a wire grid model of all conducting surfaces. A wire grid model consists of a mesh of closely spaced, connected wires, which are close enough together to approximate a solid conducting surface. Building a wire grid model of a ship is a time consuming, tedious process, requiring detailed blue prints and considerable experience. The resulting computer model requires the resources of a large main frame computer system.

In some cases, a simplified antenna model may be used to avoid the expense of wire grid models. This requires good judgement and usually some additional information, such as measurements of the antennas in similar shipboard environments. The simplified model provides an upper bounds on the fields and the measurements are used to determine a suitable safety margin.

The first step is to develop and validate, if possible, a model of the antenna. This is a process of deciding how many wires and segments are required to achieve acceptable accuracy. This process will be described for the development of a MININEC model of the Miniloop antenna.

## BACKGROUND

The "Mini" Numerical Electromagnetics Code, or MININEC (reference 1), is a method of Moments computer program for analysis of thin wire antennas. A Galerkin procedure is applied to an electric field integral equation to solve for the wire currents. This formulation results in an unusually short computer program suitable for implementation on a microcomputer. Hence, MININEC is written in a BASIC language compatible with many popular microcomputers.

MININEC solves for impedance and currents on arbitrarily oriented wires, including configurations with multiple wire junctions, in free space and over a perfectly conducting ground plane. Options include lumped parameter impedance loading of wires and calculation of near zone and far zone fields. Both near electric fields and near magnetic fields can be determined for free space and over a perfectly conducting ground. The far zone electric fields and radiation pattern (power pattern) can also be determined for free space and perfectly conducting ground.

The miniloop is a single turn, HF loop antenna which has been used for communications by the U. S. Coast Guard for both transmit and receive. It features capacitive remote tuning and inductive feed.

There are two versions of the Miniloop antenna (see reference 2). Version MLA-1/E is for use in the band from 1.8 MHz to 14.5 MHz. Version MLA-2/D is for use from 3 MHz to 24.5 MHz. Both consist of a large loop mounted on a pedestal. The loop is excited from a much smaller feed loop and turned via a variable capacitor at the top of the large loop. Figure 1 illustrates the basic configuration.



## THE MININEC MODELS

For MININEC, the main loop of the Miniloop antenna is represented by a series of one segment wires connected end to end to form the main loop. A convergence test is performed to determine the number of wires or segments required for reasonable accuracy.

The impedance of the Miniloop is not known. Referring to the open literature, a loop whose characteristics are well established is chosen. Figure 2 shows the convergence test for a one wavelength circumference loop in free space. The admittance given by R.W.P. King (from reference 3) is used to measure convergence. Based on this data, a 22 segment or 22 sided polygon model of the loop is selected. Figure 3 shows the performance of this model over a wide band of frequencies. Figure 3 is a comparison of the MININEC model to the published data by R.W.P. King. The Miniloops are used in the region below the first self resonance. It is seen in Figure 3 that the MININEC model tracks the theory very well below resonance.

Using the MININEC loop model, the Miniloop configuration of Figure 1 was explored further. It has been determined that the currents on the mast support are two orders of magnitude lower than the loop currents. The mast can therefore be removed from the model without loss of accuracy. Likewise, the feed loop can also be removed from the model. The feed loop serves the purpose of impedance matching and does not contribute significantly to the properties of the RF fields. Hence, the loop model is simplified to a circular loop over a perfectly conducting ground plane. For each version of the Miniloop, the diameter of the loop model is adjusted to give the same area as the Miniloop version, i.e., the loop model has the same self resonance as the Miniloop version

Both versions of the Miniloop use a vacuum capacitor located at the top of the large loop to tune the antenna to resonance at the operating frequency. The MININEC model must be exercised once at each desired frequency to determine the value of reactance required for tuning. The model is excited or fed at the load point. The negative of the reactance of the antenna input impedance is the required load value. A second run with this reactance at the load point, but fed at the bottom of the loop, is generally done to verify the tuned condition.

## MINILOOP EFFICIENCY

One way to determine the radiation efficiency of an antenna system is as follows:

The system efficiency is:

$$\eta = \frac{BW_0}{BW_m}$$

where  $BW_0$  is the ideal bandwidth from the MININEC model and  $BW_m$  actual bandwidth achieved or measured. The bandwidth of the Miniloops on a ground plane has been previously measured by NAVOCEANSYSCEN. The results from references 2 and 4 are given in figure 4.

The ideal bandwidth is determined from the MININEC model and the  $Q$  as follows:

$$BW_0 = \frac{f_0}{Q_0}$$

Where the  $f_0$  is the operating frequency and  $Q_0$  is the ideal  $Q$  determined by the slope-reactance technique given in Jasik (reference 8). To apply this technique, the change in reactance of the tuned antenna is determined for a small change in frequency, and the  $Q$  is determined from

$$Q_0 = \frac{\left| X_a \right| + f_0 \left| \frac{dX_a}{df} \right|}{2R}$$

Where  $X_a$  is the antenna reactance and  $R$  is the radiation resistance at the frequency  $f_0$ . Figure 5 shows the efficiency versus frequency for the two Miniloop antennas as determined by this procedure.

## SUMMARY

The process for development and validation of a MININEC model has been illustrated. In this case the Miniloop model has been used to determine antenna efficiency, which in turn can be used to set power levels for RF near field predictions.

## REFERENCES

1. NOSC TD 938, "The New MININEC (Version 3): a Mini-Numerical Electromagnetic Code", J. C. Logan and J. W. Rockway, Sep. 1986
2. Department of Transportation/U. S. Coast Guard, "Instruction Booklet for MLA-1/E and MLA-2/D Miniloop Antenna Systems", Electronics Engineering Division, U.S. Coast Guard Station, Alexandria, Va., 1 Mar. 1982.
3. R. W. P. King, "Tables of Antenna Characteristics", IFI/Plenum Data Corporation, New York 1971
4. NELC TD 317, "MLA-1 Miniloop Antenna: A Technical Evaluation", by J. L. Lievens and D. W. DuBrul, 10 May 1974.

DIMENSIONS IN METERS		
	MLA-D/2	MLA-E/1
A	1.9	2.1
B	.9	1.5
C	.18	.3
D	1.98	1.98

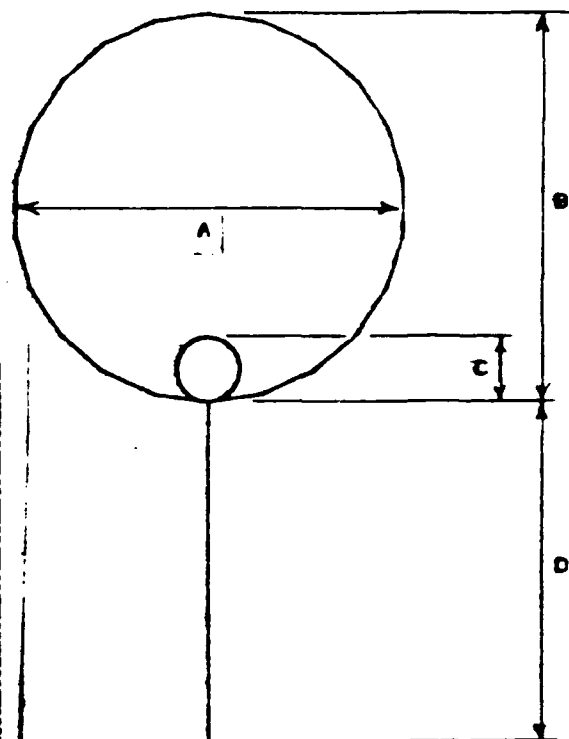
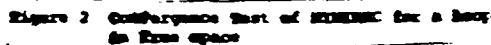


Figure 1 Illustration of Basic Shallop Configuration



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# MININEC LOOP ANTENNA BEHAVIOR

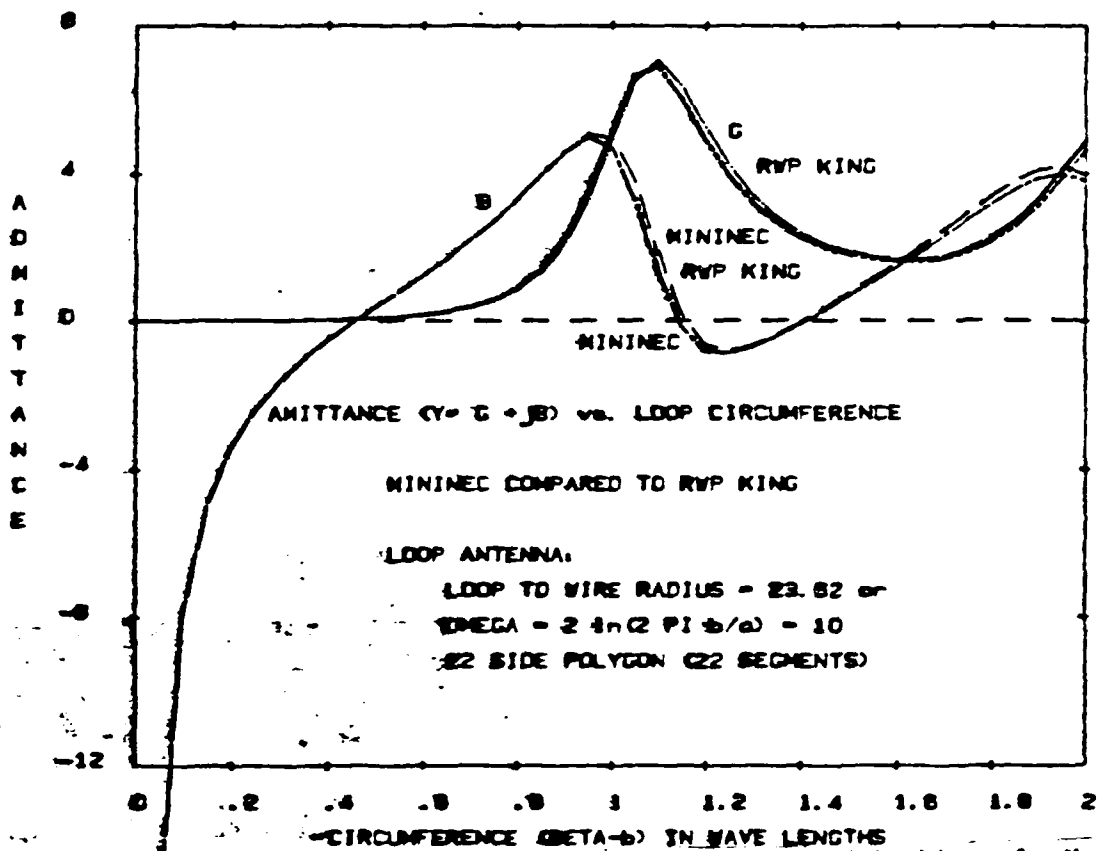


Figure 3 Comparison of the admittance from the MININEC loop model to the theory of R.V.P. King (reference 7)



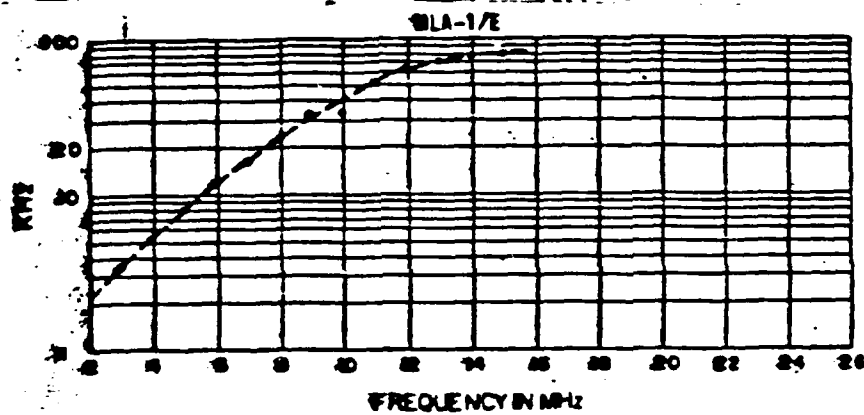
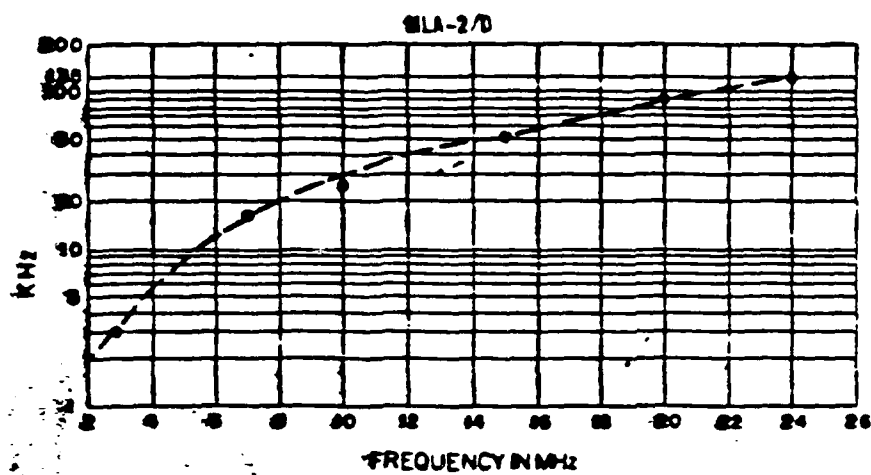


Figure 4 Half-power bandwidth measured on a ground plane

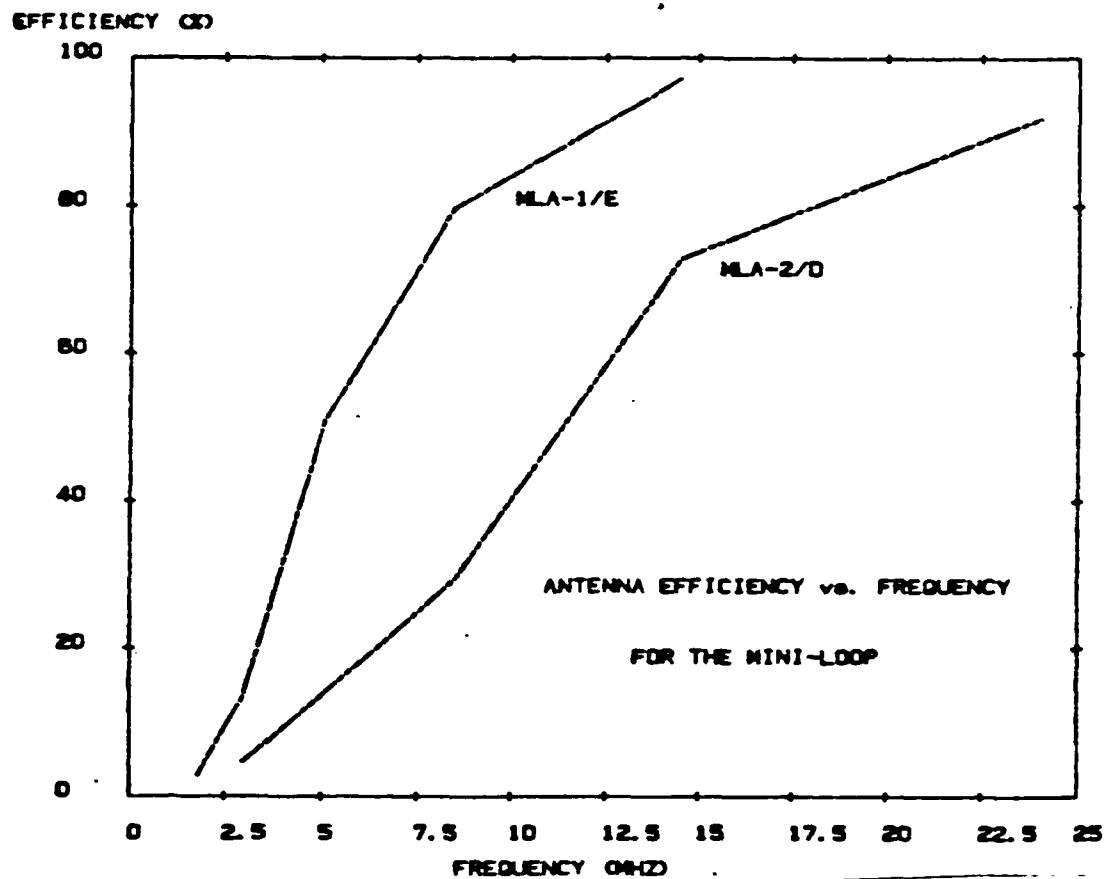


Figure 5 Mini-loop efficiency based on the measured bandwidth and the MINIMC Model.

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